ORNL/CDIAC-139

# Carbon Dioxide Information Analysis Center
# and
# World Data Center for Atmospheric Trace Gases

## Fiscal Year 2002
## Annual Report

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# 1. Introduction

The Carbon Dioxide Information Analysis Center (CDIAC), which includes the World Data Center (WDC) for Atmospheric Trace Gases, is the primary global change data and information analysis center of the U.S. Department of Energy (DOE). More than just an archive of data sets and publications, CDIAC has, since its inception in 1982, enhanced the value of its holdings through intensive quality assurance, documentation, and integration. Whereas many traditional data centers are discipline-based (for example, meteorology or oceanography), CDIAC's scope includes potentially anything and everything that would be of value to users concerned with the greenhouse effect and global climate change, including atmospheric concentrations and atmospheric emissions of carbon dioxide ($CO_2$) and other radiatively active gases; the role of the terrestrial biosphere and the oceans in the biogeochemical cycles of greenhouse gases; long-term climate trends; the effects of elevated $CO_2$ on vegetation; and the vulnerability of coastal areas to rising sea levels.

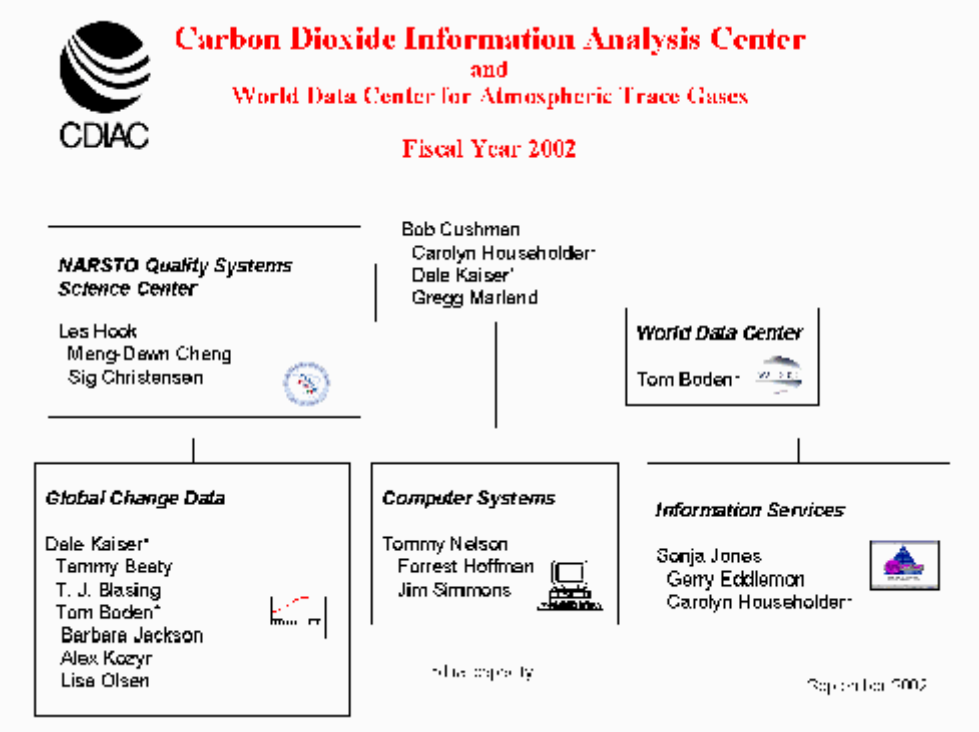
CDIAC is located within the Environmental Sciences Division (ESD) at Oak Ridge National Laboratory (ORNL) in Oak Ridge, Tennessee. CDIAC is co-located with ESD researchers investigating global-change topics, such as the global carbon cycle and the effects of carbon dioxide on climate and vegetation. CDIAC staff are also connected with current ORNL research on related topics, such as renewable energy and supercomputing technologies.

CDIAC is supported by the Climate Change Research Division (Jerry Elwood, Director) of DOE's Office of Biological and Environmental Research. CDIAC represents DOE in the multi-agency Global Change Data and Information System (GCDIS). Wanda Ferrell is DOE's Program Manager with overall responsibility for CDIAC. Roger Dahlman is responsible for CDIAC's AmeriFlux tasks, and Anna Palmisano for CDIAC's Ocean Data tasks.

CDIAC is made up of three groups (Data Systems, Information Services, and Computer Systems), as well as the World Data Center for Atmospheric Trace Gases and the NARSTO Quality Systems Science Center, with 18 full-time or part-time staff (see Fig. 1.1). The following section provides details on CDIAC's staff and organization.

- The Data Systems Group identifies and obtains databases important to global-change research; analyzes data; compiles needed databases; provides data management and support to specific programs [e.g., NARSTO, Free Air $CO_2$ Enrichment (FACE), AmeriFlux, Oceans]; and prepares documentation to ensure the long-term utility of CDIAC's data holdings.
- The Information Services Group responds to data and information requests; maintains records of all request activities; analyzes user statistics; assists in Web development and maintenance; and produces CDIAC's newsletter (*CDIAC Communications*), the annual reports, and various information materials.
- The Computer Systems Group provides computer system support for all CDIAC and WDC activities; designs and maintains CDIAC's computing system network; ensures compliance with ORNL/DOE computing security regulations; ensures long-term preservation of CDIAC data holdings through systematic backups; evaluates, develops, and implements software; ensures standards compliance; generates user statistics; provides Web design, development, and oversight; and provides systems analysis and programming assistance for scientific data projects.

**Figure 1.1 CDIAC Organizational Chart.**




## 1.1 Our Philosophy

Our philosophy can be expressed in terms of five interrelated principal objectives:

- Focus on the data and information products that are most in demand by our diverse user community of researchers, educators, students, policymakers, corporate officials, and the interested lay public. These products include the landmark record of rising atmospheric $CO_2$ at Mauna Loa, Hawaii; long-term U.S. global climate data; and global, regional, and national $CO_2$ emissions from fossil-fuel combustion.
- Emphasize data quality so that our understanding of global climate change is based on reliable information.
- Thoroughly document important databases so that 20 or more years from now, users (especially those who are not experts in the particular disciplinary area) will be able to understand how a database was produced and what the data mean.
- Provide proper credit to data contributors so that our users will understand that the data they receive from us originated not with CDIAC but rather with the investigators who so generously chose to share their data with CDIAC.
- Offer data and information to all users without restriction or charge so that society receives the greatest possible benefit from the originating research programs. Take advantage of current developments in computing technologies for data archival and distribution so that we provide a secure home for important data and provide the information to our users in the format most appropriate for them. At the same time, CDIAC appreciates that many users still prefer to receive information in more traditional formats, and we do our best to accommodate the diversity in the needs of our user community.

## 1.2 CDIAC Staff Listing

**CDIAC Staff in FY 2002**

| Staff | Phone no. (Area code - 865) | Internet address (@ornl.gov) | Function |
|---|---|---|---|
| Tammy Beaty | 574-0119 | beatytw | Numeric Data Analyst |
| T. J. Blasing | 574-7368 | blasingtj | Physical Scientist |
| Tom Boden* | 241-4842 | bodenta | Director, WDC, Atmospheric Trace Gases; Ecologist |
| Meng-Dawn Cheng | 241-5918 | chengmd | NARSTO QSSC Chief Scientist |
| Sig Christensen | 574-7394 | christensen1 | NARSTO Data Analyst |
| Bob Cushman | 574-4791 | cushmanrm | Director, CDIAC |
| Gerry Eddlemon | 574-7337 | eddlemongk | Environmental Scientist |
| Forrest Hoffman | 576-7680 | hoffmanfm | World Wide Web Specialist |
| Les Hook | 241-4846 | hookla | NARSTO QSSC Director |
| Carolyn Householder* | 576-2118 | householdecr | Information Services<br>CDIAC Secretary |
| Barbara Jackson[a] | 574-8680 | jacksonbl | Computer Scientist |
| Sonja Jones | 574-3645 | jonessb1 | Task leader, Information Services |
| Dale Kaiser* | 241-4849 | kaiserdp | Meteorologist<br>Task Leader, Global Change Data |
| Alex Kozyr | 576-8449 | kozyra | Oceanographer |
| Gregg Marland | 241-4850 | marlandgh | Senior Scientist |
| Tommy Nelson[b] | 574-0769 | nelsontr | Task leader, Computer Systems |
| Lisa Olsen | 241-5921 | olsenlm | Geographer |
| Jim Simmons[c] | 574-1060 | simmonsjw | Workstation Specialist |

[a] Computer Science and Mathematics Division, ORNL
[b] Computational Sciences and Engineering Division, ORNL
[c] Networking and Computing Technologies, ORNL
*Dual Capacity

*NOTE: Staff listing subject to change-please visit the CDIAC Web site for staff updates.*

# 2. Focus Areas


## 2.1 AmeriFlux

(*http://public.ornl.gov/ameriflux/Participants/Sites/Map/index.cfm*)

Since 1997, CDIAC has been funded by DOE to provide data management support for the AmeriFlux network. Using the eddy covariance (EC) method, AmeriFlux investigators measure the net flux of $CO_2$ to and from major terrestrial ecosystems. The aim of this long-term, continuous monitoring network is two-fold. The first is to better understand the factors regulating $CO_2$ exchange including soil processes, vegetation structure, physiology, and stage of succession. The second is to determine principal feedbacks that affect future states, such as response to changes in climate, air pollution, and $CO_2$ concentrations.

The scientific objectives of AmeriFlux are to establish an infrastructure for guiding, collecting, synthesizing, and disseminating long-term measurements of $CO_2$, water, and energy exchange involving a variety of ecosystems; to collect critical new information to help define the current global $CO_2$ budget; enable improved predictions of future concentrations of atmospheric $CO_2$; and to enhance understanding of carbon fluxes, net ecosystem production (NEP), and carbon sequestration in the terrestrial biosphere.

The present AmeriFlux network now comprises approximately 100 sites in Brazil, Canada, Costa Rica, Mexico, and the United States. These sites span a large variety of ecosystems, climate regimes, elevations, and stand ages.

The primary responsibilities of the CDIAC AmeriFlux data archive are to continually archive AmeriFlux data; examine contributed AmeriFlux data to ensure quality and consistency; assemble consistent documentation to ensure long-term use of AmeriFlux data; compile ancillary information for each AmeriFlux site [e.g., leaf area index (LAI), land-use histories] for the purpose of creating network-wide databases; facilitate regional, national, and global-scale modeling efforts; and create and maintain the AmeriFlux Web site.

The AmeriFlux data archive at CDIAC offers two types of data: preliminary and final. Preliminary data are contributed by AmeriFlux principal investigators (PIs). The file formats and contents are unchanged from their original submission state. Any descriptive files provided are those furnished by the site PIs. The values provided in these preliminary files have been scrutinized by the PIs but are subject to change. Preliminary AmeriFlux data are generously contributed to CDIAC and made available immediately on the CDIAC FTP server (*ftp://cdiac.esd.ornl.gov/pub/ameriflux/data/*). Preliminary AmeriFlux data sent to CDIAC are checked, processed into a consistent data format, and documented by CDIAC before release as a final data set. All data issues investigated by CDIAC are resolved with the contributing PIs, and no values are changed without the approval of the contributing PIs.

### 2.1.1 Noteworthy Developments During FY 2002

The AmeriFlux data archive at CDIAC has continued to grow and at the end of FY 2002, the collection included over 170 site-years of data from 48 sites covering the period 1991!2002. Collectively, over

30 million data values are now available from the AmeriFlux data archive at CDIAC.
AmeriFlux data, information, and presentations continue to be very popular. Over 100,000 users have accessed the AmeriFlux Web site since August 2001, and during FY 2002, approximately 24,000 unique computer systems accessed AmeriFlux data on the CDIAC FTP server.

Among the numerous FY 2002 developments in support of the AmeriFlux data management efforts at CDIAC, the new AmeriFlux Data Viewing and Retrieval System (*http://cdiac.ornl.gov/programs/ameriflux/data_system/aamer0.html*) was launched after a prototype was developed during FY 2001. This Web-based interface offers "one-stop shopping" for AmeriFlux data. Users may query a network-wide AmeriFlux database by measurement parameter, sampling time, and site location and then view the results of their query graphically or download files according to user specifications. The network-wide database draws on CDIAC's core AmeriFlux quality assurance efforts in offering a database with common units, variable nomenclature, and time-reporting intervals. The new interface represents the third means by which users may access AmeriFlux data from CDIAC, complementing previous access to site-specific data via the Web site (*http://public.ornl.gov/ameriflux/Data/index.cfm*) or by direct FTP transfer (*ftp://cdiac.esd.ornl.gov/ftp/ameriflux/data*). During FY 2002, approximately 150 users retrieved data using the new interface.

Dr. Lianhong Gu joined ORNL and the AmeriFlux data effort in the summer of FY 2002. Lianhong's initial work focused on investigating a potential photosynthetic enhancement at an AmeriFlux site, Harvard Forest, following the 1991 Mt. Pinatubo eruption and exploring the feasibility of applying a statistics-based friction velocity correction (i.e., U-star correction) to AmeriFlux site data. Lianhong's Mt. Pinatubo analysis looking at diffuse radiation levels and photosynthetic enhancement at Harvard Forest culminated in a paper accepted by *Science* and scheduled for publication in FY 2003.

During the summer of FY 2002, CDIAC hosted summer student Manuel Antonio Arce Garcia (Universidad del Sagrado, Corazon, Puerto Rico). Manuel spent the summer tracking down site information, particularly instrument and methodology information, for AmeriFlux sites and populating the information into a centralized Access database shared by the AmeriFlux and FLUXNET data activities at ORNL. Information in the Access database is displayed dynamically on the AmeriFlux Web site pages thanks to programs written by FY 2001 summer student Tom Kollar (University of Rochester). Detailed site characterizations, including instrument information and measurement methodologies like those assembled by Manuel, are essential for AmeriFlux synthesis efforts. Numerous questions rely on the availability of site information. For example, are there appreciable differences between $CO_2$ fluxes measured with open-path infrared gas analyzers (IRGA) and fluxes measured with closed-path IRGAs? Over the 2002 summer, Manuel was able to enter over 5000 pieces of information into the Access database.

### 2.1.2 FY 2003 AmeriFlux Plans

Several efforts are planned for FY 2003 to support the AmeriFlux data management activities at CDIAC. Tom Boden and team will continue to support the AmeriFlux/Model/MODIS Evaluation Exercise (*http://public.ornl.gov/ameriflux/Analysis/Model_Evaluation/index.html*) initiated by Dr. Steve Running (University of Montana) in FY 2000. Efforts will continue on the data interface mentioned above including adding data recently submitted and developing additional querying capabilities (e.g., principal investigator or investigators). Core AmeriFlux data activities will continue as always. Tom Boden will attend both the annual AmeriFlux Science Meeting and the NACP Implementation Workshop. In the area of AmeriFlux

Web maintenance, emphasis will be placed on improvements to heighten the prominence of the AmeriFlux "fair-use" agreement. Lianhong Gu will continue his evaluation of a statistical U-star correction approach during FY 2003. Summer students will be evaluated in the hope a computer science major can be brought aboard to improve our ability to identify AmeriFlux data users and their host institutions.

### 2.2 Free-Air $CO_2$ Enrichment (FACE)


(*http://cdiac.ornl.gov/programs/FACE/face.html)*

Free-Air $CO_2$ Enrichment (FACE) technology provides a means to modify the atmospheric $CO_2$ concentrations around growing plants in their natural environment to identify effects of future $CO_2$ increases. Unlike growth chambers and greenhouses, no containment is required with FACE designs. Environmental conditions that are difficult or impossible to replicate in an indoor environment, such as realistic combinations of weather variables (e.g., temperature, precipitation, wind speed, humidity, direct sunlight, and pollination) are incorporated into the FACE experiments. In addition, the FACE program reduces or eliminates plant size or growth problems caused by the constraint of enclosures (although the system must be sized, or expandable, to accommodate the anticipated future size of the plants during the lifetime of the experiment). Therefore, long-term studies of natural communities, incorporating plants of varying ages and sizes, may be conducted. FACE field data represent plant and ecosystem responses to varying concentrations of atmospheric $CO_2$ possible later in this century, in a natural setting.

FACE research technology creates a platform for multidisciplinary, ecosystem-scale research on the effects of elevated atmospheric $CO_2$ concentrations over extended periods of time. In doing so, a large amount and variety of high-$CO_2$-grown plant material can be produced to support the research of many cooperating scientists studying different aspects of an ecosystem's response to $CO_2$ enrichment. This concurrent use by numerous independent scientists provides the potential to gain new insights into ecosystem responses that are difficult or impossible to obtain with smaller scale, enclosed, studies.

CDIAC continued to develop its FACE Web site to support the global network of approximately 30 research sites that are operational, in development, or proposed. CDIAC also began to archive and distribute data from the ORNL FACE site; the first of these data sets was contributed by Jeffrey Riggs, Lynn Tharp, and Richard Norby. It includes weather-related variables (e.g., air temperature, soil temperature, relative humidity, precipitation, wind speed and direction, solar radiation and sun angle) measured at the FACE site, and atmospheric $CO_2$ concentrations measured within the FACE site and within a nearby ambient site with similar ecological characteristics. The period of record is 1999!2002. Future data sets will also include tree basal area and other ecological response variables.

**Yield data from Paul Newton's New Zealand FACE site online**

Data from the FACE research site in Bulls, New Zealand, are now online (*http://cdiac.ornl.gov/programs/FACE/nzdata/nzdata.html*). The first data set from this pasture site, contributed by Paul Newton and Harry Clark (Agresearch, Palmerston North, New Zealand), quantifies the effects of carbon dioxide enrichment (ambient, 360 ppm; versus elevated, 475 ppm) and management (grazed versus ungrazed plots) on plant dry weight. Future data sets will include effects on species composition.

**Initial list of standardized variable names/definitions/units online**

CDIAC's FACE Web site now includes a standardized nomenclature list (*http://cdiac.ornl.gov/programs/FACE/variables.html*), which details variable names, definitions, and units for FACE data sets distributed by CDIAC. For example, users now can easily determine that, wherever they encounter the term PYRANxm, it refers to integrated incident total radiation (pyrarometer measurement), at x meters height, and is expressed in units of watts per square meter. This standardization will facilitate comparison and syntheses across data sets and across FACE sites.

### 2.2.1 FY 2003 FACE Plans

In FY 2003, we plan to add more variables to the FACE data for the ORNL site (leaf area index), as well as continuing to add to the $CO_2$ and weather files from that site. We also hope to add more data from the New Zealand site and to include data from additional sites, such as the FACTS II (Rhinelander, Wisconsin) site. As we do so, we expect to continue adding to our list of standardized variable names, definitions, and units.

## 2.3 NARSTO Quality Systems Science Center (QSSC)

(*http://cdiac.ornl.gov/programs/NARSTO/narsto.html*)

The tri-national (Canada, United States, and Mexico) NARSTO (originally North American Research Strategy for Tropospheric Ozone) program has broadened its objectives to include atmospheric pollutants besides ozone. NARSTO is a public/private partnership, open to science agencies, regulatory agencies, regulated industries, academic institutions, environmentalists, and public interest groups in North America. Its primary mission is to coordinate and enhance policy-relevant scientific research and assessment of tropospheric pollution behavior, with the central programmatic goal of determining workable, efficient, and effective strategies for local and regional air-pollution management.

In January 1997, DOE's Environmental Sciences Division began their sponsorship of the NARSTO Quality Systems Science Center (QSSC) within CDIAC. The QSSC reports to the NARSTO Executive Steering Committee through the NARSTO Management Coordinator and collaborates with the NARSTO science teams.

The QSSC works to ensure that relevant quality management systems are planned and implemented by NARSTO technical programs. The *NARSTO Quality Systems Management Plan (QSMP)* (*http://cdiac.ornl. gov/programs/NARSTO/pdf/qsmp_current_version.PDF*) and the *Quality Planning Handbook (QPHB)* (*http://cdiac.ornl.gov/programs/NARSTO/pdf/qphb_current_version.PDF*), developed and maintained by the QSSC, provide the framework within which all quality-related activities are conducted.

The QSSC reviews project management and fieldwork planning documents and provides information to NARSTO partners seeking assistance with quality assurance, quality control, data management, and data archival.

The QSSC plans and coordinates NARSTO data management, data archival, and data dissemination activities. Timely sharing of, and ready access to, quality-assured NARSTO data and research products (e.g., computer models, methods, procedures, and reports) by the scientific community is essential to the success of the NARSTO program.
Data archive format specifications are implemented in the NARSTO Data Exchange Standard template. The QSSC performs a final quality assurance check of data sets submitted for archival, prepares archive documentation, and coordinates their transfer to the publicly available NARSTO permanent data archive (PDA) at the National Aeronautics and Space Administration (NASA) Langley Distributed Active Archive Center (DAAC). Data archived during 2002, including several Southern Oxidants Study (SOS) Nashville 1999 and Environmental Protection Agency (EPA) Supersites data sets, are available online at *http://eosweb.larc.nasa.gov/project/narsto/table_narsto.html*.

NARSTO quality systems and data management documents are available online at *http://cdiac.ornl.gov/programs/NARSTO/*. This Web site received approximately 400 visits per month.

In addition to these quality and data management activities, the QSSC continues to maintain the NARSTO Measurement Methods Compendium for ozone and particulate matter sampling and analysis technologies and methodologies. Method descriptions are available online at *http://cdiac.ornl.gov/programs/NARSTO/.*

QSSC staff expertise includes atmospheric chemistry, quality systems management, environmental data quality management, and data management coordination.

The FY 2002 QSSC's activities fall into three general areas: data management and archiving, data management support for projects, and external interactions.

### 2.3.1 Data Management and Archiving

During FY 2002, the following tasks were accomplished.

1. Development of a NARSTO Data Usage and Acknowledgment Policy, which was posted on the QSSC Web site.

2. Release of Version 2.3 of the Data Exchange Standard (DES) file format. QSSC staff constructed and maintained companion standard value reference tables for chemical and physical variable names [e.g., over 750 chemical names and CAS (Chemical Abstracts Service) numbers; 50 chemical constituents without CAS numbers; and 150 variable names for physical measurements without CAS numbers]. Corresponding version updates and enhancements were implemented in the DES quality assurance Read and Verify Code.

3. Maintenance of the NARSTO Data and Information Sharing Tool (DIST). DIST is a Web-based index and clearinghouse of atmospheric measurement, chemistry data, and metadata. Data are indexed using consistent metadata categories to support searching by project, location, date, keyword, and investigator. Data providers can use the Web-based DIST to conveniently enter metadata and to link their data and documents into the searchable DIST index. Atmospheric chemistry and meteorology data from the Southern Oxidants Study (SOS) Nashville 1995 and 1999 Study were made available to the public. An

FTP site is associated with DIST for storage and retrieval of data sets. DIST is a key component in the flow of data from projects to the NARSTO PDA, with output capabilities that facilitate metadata and data archiving.

### 2.3.2 Data Management Support for Projects

The QSSC provides assistance to NARSTO research managers, principal investigators, and data managers. During FY 2002, the following tasks were accomplished.

1. Interactions were initiated with the Mexico City Metropolitan Area Program, sponsored by the Massachusetts Institute of Technology. We consulted on questions regarding database design for atmospheric measurements and implementation of NARSTO standard values.

2. The QSSC also provided data management support to the U.S. Environmental Protection Agency (EPA) Particulate Matter (PM) Supersites Program. In consultation with EPA and the data coordinators of the Supersite projects, the QSSC, with the financial support of EPA, is coordinating the following activities:

    a. Support for development and maintenance of a consistent set of metadata for the Supersites measurement data. Metadata are the data that describe, for measured results, the important details as to: what, where, when, how, why, and by whom. Several working groups were established to develop consensus on formats for site names, variable names, units, methods, and flags. Periodic teleconference discussions keep the process moving. The Supersites Program provides quality-assured data to the QSSC for archiving in accordance with the published NARSTO guidelines.

    b. Maintenance of the NARSTO DIST for the Supersites Program to support sharing of data among investigators and to use DIST's output capabilities to facilitate data archiving. The addition of new features and modifications to metadata will be made as necessary for effective implementation. The addition of new DIST users, system administration, and user support is included in this activity.

    c. Implementation of a Supersites FTP Site to support the sharing of data among Supersites Program participants. Supersite project data coordinators may add and maintain data on the FTP site to allow program-wide access to data, while not permitting access to secure project systems.

    d. Archiving of Supersites data sets to the NARSTO PDA (e.g., Houston's “Washburn Tunnel Air Quality Monitoring Data” and Los Angeles's “Scanning Mobility Particle Size Data”).

### 2.3.3 External Interactions

Bill Sukloff (Environment Canada, Meteorological Service of Canada) visited the QSSC. This was Bill's fourth working visit to Oak Ridge. During his visit, QSSC staff worked with Bill on the continued development and updating of the Data Exchange Standard archive data format Read and Verify Program and accompanying reference tables. Bill is the data coordinator for several Canadian air quality monitoring networks and NARSTO-affiliated intensive air quality investigations.

These various coordinated efforts, to address NARSTO data management activities in a coordinated and efficient manner, encourage sharing of the considerable technical, measurement, and data management knowledge and system resources that already exist across the Supersites projects, NARSTO, EPA, and externally. Staff from other NARSTO, EPA, and similar atmospheric research projects are encouraged to take advantage of these results and contribute their experience and data. This coordinated effort, envisioned as a model for future cooperation, is a prime example of why NARSTO was formed and how it can function.

### 2.3.4 Meetings Attended

- Les Hook, Director, attended the Annual Executive Assembly/Steering Committee Meeting, Washington, D.C., April 2002.

- Les Hook presented "Data and Metadata Reporting Standards for the U.S. Environmental Protection Agency's PM Supersites Research Program" at the *21st Annual National Conference on Managing Environmental Quality Systems* (Phoenix, Arizona, April 2002). The paper was co-authored with Sigurd Christensen (ORNL) and William Sukloff (Environment Canada, Meteorological Service of Canada). The paper was subsequently published as Hook, Les A., Sigurd W. Christensen, and William B. Sukloff. 2002. Data and Metadata Reporting Standards for the U.S. Environmental Protection Agency's PM Supersites Research Program. In *Quality Assurance*, 9 155 ! 164, 2001/2002.

## 2.4 Ocean Data

(*http://cdiac.ornl.gov/oceans/home.html*)

The World Ocean Circulation Experiment (WOCE) Hydrographic Program (WHP) is a major component of the World Climate Research Program with the overall goal of better understanding the ocean's role in climate and climatic changes resulting from both natural and anthropogenic causes. The levels of $CO_2$ in the oceans are unevenly distributed because of complex circulation patterns and biogeochemical cycles. Although $CO_2$ is not an official WOCE measurement, a coordinated effort, supported in the United States by DOE, was made on WOCE cruises through 1998 to measure the global-scale and temporal distributions of total carbon dioxide ($TCO_2$) and related parameters.

Goals of the survey were to estimate the meridional transport of inorganic carbon in a manner analogous to the estimation of the transport of oceanic heat and to build a database suitable for inclusion in carbon cycle modeling and the estimation of anthropogenic $CO_2$ increase in the oceans. The $CO_2$ survey took advantage of the sampling opportunities provided by the WHP cruises during this period. The final data set is expected to cover approximately 23,000 stations from 42 WOCE cruises.

CDIAC provides data management support for the Joint Global Ocean Flux Study (JGOFS) $CO_2$ measurements taken aboard research vessels during WHP cruises. DOE has sponsored $CO_2$ measurement operations and continues to sponsor CDIAC's data support activities, which include data archival, data checking and evaluation, data documentation, and data dissemination. All $CO_2$-related data are checked before documentation and distribution. Through the end of FY 2000, DOE-supported investigators had

collected $CO_2$ measurements on 42 WOCE cruises. CDIAC has received data from all of these cruises, and these data sets have undergone quality assurance checks; 28 are fully documented as numeric data products (NDPs). CDIAC also received carbon-related data from six international WOCE cruises.

CDIAC provides data management support for the GLobal Ocean Data Analysis Project (GLODAP). GLODAP is a cooperative effort of investigators funded for synthesis and modeling projects through the National Oceanic and Atmospheric Administration (NOAA), DOE, and the National Science Foundation (NSF). Cruises conducted as part of the WOCE, JGOFS, and the NOAA Ocean-Atmosphere Carbon Exchange Study (OACES) during the 1990s have generated oceanographic data of unparalleled quality and quantity.

Most of the data have been reported to national archive facilities but have not been integrated into an internally consistent global data set. GLODAP will compile that data set and examine the global distribution and inventories of oxygen, nutrients, natural and anthropogenic carbon species, natural and bomb-produced radiocarbon ($^{14}C$), and $^{13}C$. These estimates will be used to infer nutrient remineralization ratios (Redfield ratios) and the rate of anthropogenic $CO_2$, $^{13}C$, and bomb $^{14}C$ uptake in the oceans. These estimates provide an important benchmark for comparison with future observational studies. They also provide tools for the direct evaluation of numerical models of the transport and fate of carbon in the oceans. CDIAC has opened a new Web page for the final GLODAP products *(http://cdiac.ornl.gov/oceans/GLODAP/Glodap_home.htm*).

CDIAC provides data management support for the project CARINA (CARbon dioxide In the North Atlantic ocean). The CARINA objectives are:

- to bring together research groups that measure $CO_2$ in the North Atlantic Ocean;
- to create an inventory of $CO_2$ measurements carried out in the North Atlantic Ocean;
- to make available unpublished data to the data contributors (data access);
- to form working groups that cooperate on various aspects of the $CO_2$ system in the North Atlantic; and
- to exchange information concerning $CO_2$ research in the North Atlantic.

CDIAC also plays a major role in the $CO_2$ data management for the North Pacific Marine Science Organization (PICES) Working Group 17 (WG17). The main goal of the WG17 is to work with the Japan Oceanographic Data Center (JODC), National Oceanographic Data Center (NODC), CDIAC, Marine Environmental Data Service (MEDS), et al. to complete an International North Pacific data set for $CO_2$ and $CO_2$-related parameters $TCO_{2)}$, total alkalinity (TALK), partial pressure of carbon dioxide ($pCO_2$), etc. Another goal is to encourage PICES countries (Japan, South Korea, China, Canada, Russia, and the United States) and non-PICES countries to contribute data and information on data to the PICES data inventory.

Alex Kozyr participated in the sampling cruise of the Australian research vessel, R/V *Aurora Australis*, in the Southern Ocean, part of a research crew of 70 oceanographers from 11 countries (see cruise photos at *http://cdiac.ornl.gov/oceans/cruise.html*). The cruise, which began in Hobart, Tasmania, Australia, on October 29 and returned there on December 13, reached the Antarctic shelf ice. During the cruise, Alex participated in sampling of ocean carbon and related chemical and physical parameters from stations every 30 km along the route. The cruise resampled one of the few lines in the Southern Ocean where anthropogenic $CO_2$ has been observed throughout the water column and found to be moving northward in the bottom waters. In addition to the standard $CO_2$ and alkalinity measurements used elsewhere in ocean carbon surveys (see

CDIAC's Ocean $CO_2$ Web page at *http://cdiac.ornl.gov/oceans/home.html*), the cruise provided an opportunity to test new systems for ongoing measurement of $pCO_2$ (partial pressure of $CO_2$) and $TCO_2$.

### 2.4.1 Meetings Attended

Alex Kozyr presented the poster "Electronic Tour through the Carbon Dioxide Information Analysis Center's Ocean Web page (*http://cdiac.ornl.gov/oceans/home.html*)" at the 10th Annual Meeting of the North Pacific Marine Science Organization (PICES, *http://pices.ios.bc.ca/*) in Victoria, British Columbia, Canada.

# 3. Data and Information Products

CDIAC's carbon dioxide-related products provide data and information in several areas relevant to the greenhouse effect and global climate change. These areas include records of atmospheric trace gases [$CO_2$, methane, nitrous oxide, chlorofluorocarbons (CFCs), and aerosols], global carbon cycle parameters, long-term climate records, coastal vulnerability to rising sea level, demographics, land use and ecosystems, oceanic trace gases, solar and atmospheric radiation, trace gas emissions, and vegetation response to $CO_2$ and climate.

CDIAC packages and distributes holdings in the form of data products [e.g., numeric data packages (NDPs), databases (DBs), and a computer model package (CMP)] and printed publications. All products are provided free of charge and are available while supplies last. Data files and documentation (text or HTML version), which accompany the data products, may be accessed and downloaded from CDIAC's Web site (*http://cdiac.ornl.gov/*), from CDIAC's anonymous FTP area (*ftp://cdiac.ornl.gov*), or requested directly from CDIAC on various types of media (e.g., CD-ROM, floppy diskette). Printed reports are available from CDIAC on request. All technical questions (e.g., methodology or accuracy) should be directed to the CDIAC staff member responsible for preparing the particular data product.

During FY 2002, CDIAC published two new NDPs under the auspices of DOE. CDIAC updated seven NDPs and one DB. CDIAC also added four new records to *Trends Online* (*http://cdiac.ornl.gov/trends/trends.htm*) and updated six existing records.

## 3.1 New Products

### 3.1.1 Oceanic Trace Gases

- **Carbon Dioxide, Hydrographic, and Chemical Data Obtained During the R/V *Knorr* Cruises 138-3, -4, and -5 in the South Pacific Ocean (WOCE Sections P6E, P6C, and P6W, May 2 – July 30, 1992)** (ORNL/CDIAC-132, NDP-077) *http://cdiac.ornl.gov/oceans/ndp_077/ndp077.html*

  Contributors: Kenneth M. Johnson (Brookhaven National Laboratory), Meredith Haines (University of South Florida), Robert M. Key (Princeton University), Craig Neill (Brookhaven National Laboratory), Bronte Tilbrook (Commonwealth Scientific and Industrial Research Organisation), Rick Wilke (Brookhaven National Laboratory), and Douglas W. R. Wallace (Institut fur Meereskunde, Universitat Kiel)

  Prepared by Alex Kozyr and Tammy Beaty, CDIAC; October 2001.

  This data documentation discusses the procedures and methods used to measure $TCO_2$ and $pCO_2$ at hydrographic stations during the R/V *Knorr* oceanographic cruises 138-3, -4, and -5 in the South Pacific Ocean (Section P6). The work was divided into three legs designated as P6E, P6C, and P6W, which correspond to cruises 138-3, -4, and -5, respectively. Conducted as part of the WOCE, the P6 section began in Valparaiso, Chile, on May 2, 1992, and ended 81 days later in Sydney, Australia, on July 30, 1992. Measurements made along WOCE Section P6 included pressure, temperature, salinity [measured by a conductivity, temperature, and depth (CTD) sensor], bottle salinity, bottle oxygen, silicate, nitrate,

nitrite, phosphate, $^{14}C$, $TCO_2$, and $pCO_2$ .

$TCO_2$ was measured coulometrically by use of two Single-Operator Multiparameter Metabolic Analyzers (SOMMAs). The precision and accuracy of the measurements was ±1.65 Fmol/kg. The $pCO_2$ in discrete samples was measured using a headspace-equilibration technique and gas chromatography with precision of ~1 to 2%. The $CO_2$-related measurements aboard the R/V *Knorr* were supported by the U.S. DOE.

- **Carbon Dioxide, Hydrographic, and Chemical Data Obtained During the R/V *Meteor* Cruise 28/1 in the South Atlantic Ocean (WOCE Section A8, March 29!May 12, 1994)** (ORNL/CDIAC-135, NDP-079) *http://cdiac.ornl.gov/oceans/ndp_079/ndp079.html*

  Contributors: Kenneth M. Johnson, Kevin Wills, and Craig Neill (Brookhaven National Laboratory); Arne Koertzinger and Douglas W. R. Wallace (Institut für Ostseeforschung, Rostock-Warnemüünde, Germany)

  Prepared by: Alex Kozyr and Tammy Beaty, CDIAC; March 2002.

  This data documentation discusses the procedures and methods used to measure $TCO_2$ and the fugacity of $CO_2$ at hydrographic stations during the R/V *Meteor* oceanographic cruise 28/1 in the South Atlantic Ocean (Section A8). Conducted as part of the WOCE. The cruise began in Recife, Brazil, on March 29, 1994, and ended after 35 days at sea in Walvis Bay, Namibia, on May 12, 1994. This database supports studies of the transport of carbon dioxide within the ocean and movement of carbon dioxide between the ocean and atmosphere.

### 3.1.2 Vegetation Response to $CO_2$ and Climate

- **Throughfall Displacement Experiment (TDE) Ecosystem Model Intercomparison Project Data Archive** *http://cdiac.ornl.gov/epubs/tdemodel/tdemodel.html*

  Contributors: Paul Hanson, Jeffrey Amthor, Anthony King, and Stanley Wullschleger (ORNL Environmental Sciences Division); Robert Grant (University of Alberta, Canada); Anne Hartley (The Ohio State University); Dafeng Hui (University of Oklahoma); Raymond Hunt and Steven McNulty (U.S. Department of Agriculture); Dale Johnson (University of Nevada, Reno); John Kimball and Peter Thornton (University of Montana); Yiqi Luo (University of Oklahoma); Ge Sun (North Carolina State University); Shusen Wang (Natural Resources Canada); Matthew Williams (University of Edinburgh, United Kingdom); and Kell Wilson (U.S. Department of Commerce)

  Prepared by: Bob Cushman, CDIAC; August 2002.

  CDIAC has put data online from an intercomparison of ecosystem models using results from the TDE at ORNL. The project compares model estimates of evapo-transpiration, net ecosystem carbon exchange, production, respiration, and growth.

## 3.2 Updated Products

### 3.2.1 Atmospheric Trace Gases

- **Atmospheric $CO_2$ Concentrations ! Mauna Loa Observatory, Hawaii, 1958 ! 2001 (NDP-001)**
  *http://cdiac.ornl.gov/ndps/ndp001.html*

  Contributors: C. D. Keeling and T. P. Whorf (Scripps Institution of Oceanography, University of California)

  Updated by Tom Boden, CDIAC; June 2002.

  The Mauna Loa atmospheric $CO_2$ measurements, which began in 1958, constitute the longest continuous record of atmospheric $CO_2$ concentrations available in the world. The Mauna Loa site is considered one of the most favorable locations for measuring undisturbed air because possible local influences of vegetation or human activities on atmospheric $CO_2$ concentrations are minimal and any influences from volcanic vents may be excluded from the records. The methods and equipment used to obtain these measurements have remained essentially unchanged during the 45-year monitoring program. Data are averaged to give monthly and annual atmospheric $CO_2$ concentrations. The Mauna Loa record shows a 17.4% increase in the mean annual concentration, from 315.98 parts per million by volume (ppmv) of dry air in 1959 to 370.89 ppmv in 2001. The increase in mean annual concentration from 2000 to 2001 was 1.49 ppmv (the largest single yearly jump in the Mauna Loa record was the 2.87 ppmv increase from 1997 to 1998.)

  This precise data record is a reliable indicator of the regional trend in the concentration of atmospheric $CO_2$ in the middle layers of the troposphere and is critical to $CO_2$-related research. Atmospheric $CO_2$ records from sites in the Scripps Institute of Oceanography (SIO) air sampling network are described in Section 3.3, Trends Online.

#### 3.2.1.1 Other trace gases

- **The ALE/GAGE/AGAGE Network (DB1001)**
  *http://cdiac.ornl.gov/ndps/alegage.html*

  Contributors: R. Prinn (Massachusetts Institute of Technology); D. Cunnold, F. Alyea, D. Hartley, and R. H. J. Wang (Georgia Institute of Technology); P. Fraser and L. P. Steele (Commonwealth Scientific and Industrial Research Organisation); R. Weiss (Scripps Institution of Oceanography); P. Simmonds (International Science Consultants)

  Updated by T. J. Blasing and Sonja Jones, CDIAC; July 2002.

  This program, which began in 1978, is divided into three parts associated with three changes in instrumentation: the Atmospheric Lifetime Experiment (ALE), which used Hewlett Packard HP5840 gas chromatographs; the Global Atmospheric Gases Experiment (GAGE), which used HP5880 gas chromatographs; and the present Advanced GAGE (AGAGE). AGAGE uses a new fully automated system from the SIO containing a custom-designed sample module and HP5890 and Carle Instruments gas-chromatographic components. In the ALE/GAGE/AGAGE global network program, continuous high-frequency gas chromatographic measurements of two biogenic/anthropogenic gases (methane, $CH_4$; nitrous oxide, $N_2O$) and six anthropogenic gases (chlorofluorocarbons $CFCl_3$, $CF_2Cl_2$, and $CF_2ClCFCl_2$; methyl chloroform, $CH_3CCl_3$; chloroform, $CHCl_3$; and carbon tetrachloride, $CCl_4$) are carried out at five globally distributed sites. Additional important species ($H_2$, CO, HFC-134a, HCFC-141b, and HCFC-142b) have been added at select sites in recent years.

The current station locations are Cape Matatula, American Samoa; Ragged Point, Barbados; Cape Grim, Tasmania; Mace Head, Ireland; and Trinidad Head, California. Stations also previously existed at Cape Meares, Oregon, and Adrigole, Ireland. The current Mace Head station replaced the Adrigole station, and the station at Trinidad Head replaced the Cape Meares station.

At the time of this writing, data from all three experiments are available, and data through March 2002 are available for all five existing sites. Individual measurements (generally made 4 times daily at each site for ALE, 12 times daily at each site for GAGE, and more than 30 times daily at each site for AGAGE) and monthly summary averages are provided for each site. All ALE and GAGE data have been recalculated according to the current AGAGE calibration standards, thus creating a unified ALE/GAGE/AGAGE data set based upon the same standards. All ALE/GAGE/AGAGE data presented here are reported in the SIO-1998 calibration scale (Prinn et al., 2000).

### 3.2.2 Land Use and Ecosystems

- **Tropical Africa: Land Use, Biomass, and Carbon Estimates for 1980 (NDP-055)**
  *http://cdiac.ornl.gov/epubs/ndp/ndp055/ndp055.html*

  Contributors: Sandra Brown (Winrock International, Arlington, Virginia) and Greg Gaston (Oregon State University)

  Updated by: Lisa Olsen and Tammy Beaty, CDIAC; March 2002.

  This document describes the contents of a digital database containing maximum potential aboveground biomass, land use, and estimated biomass and carbon data for 1980. The biomass data and carbon estimates are associated with woody vegetation in Tropical Africa. These data were collected to reduce the uncertainty associated with estimating historical releases of carbon from land use change. Tropical Africa, as defined here, is comprised of countries that are located in tropical Africa [Angola, Botswana, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Congo, Benin, Equatorial Guinea, Ethiopia, Djibouti, Gabon, Gambia, Ghana, Guinea, Ivory Coast, Kenya, Liberia, Madagascar, Malawi, Mali, Mauritania, Mozambique, Namibia, Niger, Nigeria, Guinea-Bissau, Zimbabwe (Rhodesia), Rwanda, Senegal, Sierra Leone, Somalia, Sudan, Tanzania, Togo, Uganda, Burkina Faso (Upper Volta), Zaire, and Zambia].

  The database was developed using the GRID module in the ARC/INFO™ geographic information system. Source data were obtained from the Food and Agriculture Organization (FAO), the U.S. National Geophysical Data Center, and a limited number of biomass-carbon density case studies. These data were used to derive the maximum potential and actual (ca. 1980) aboveground biomass values at regional and country levels. The land-use data provided were derived from a vegetation map originally produced for the FAO by the International Institute of Vegetation Mapping, Toulouse, France.

  Analyses conducted with this database revealed that 18% of Tropical Africa was classified as closed forest and 36% was classified as open forest in 1980. Forested lands contained over 138 x $10^9$ Megagrams (Mg) of aboveground live biomass, which is equivalent to 69 x $10^9$ Mg of carbon. Closed forests and open forests had mean aboveground biomass values of 209 Mg/ha and 67 Mg/ha, respectively, in 1980. These values are around 2/3 of the world maximum potential aboveground live

biomass values of 296 Mg/ha for closed forest and 108 Mg/ha for open forest.

### 3.2.3 Climate

- **Annual and Seasonal Global Temperature Deviations in the Troposphere and Low Stratosphere, 1958!2001** (NDP-008) *http://cdiac.ornl.gov/ndps/ndp008.html*
  Contributors: James Angell (NOAA Air Resources Laboratory, Silver Spring, Maryland)

  Updated by Sonja Jones and Dale Kaiser, CDIAC; April 2002.

  Data from 1958!2001 at each of 63 radiosonde stations were used to estimate annual and seasonal temperature deviations from 1958!1977 means. The results were categorized vertically into five levels (near-surface, troposphere, tropopause, low stratosphere, and near-surface to 100 mb), and spatially into 11 regions [entire globe, Northern Hemisphere, Southern Hemisphere, Polar (60!90E) Northern and Southern Hemispheres, Temperature (30!60E) Northern and Southern Hemispheres, Subtropical (10!30E) Northern and Southern Hemispheres, Tropical (30ES-60EN), and Equatorial (10EN!10ES)]. Based on this network, Angell reported that during 1958!2001, the global mean, near-surface air temperature warmed by 0.15EC/decade and the 850!300 mb troposphere layer warmed by 0.08EC/decade. The global mean 300!100 mb tropopause layer cooled by approximately -0.2EC/decade, driven mainly by large changes in the Polar zones, and the 100!50 mb low-stratospheric layer experienced a global mean cooling of about -0.6EC/decade.

## 3.3 *Trends Online*

### 3.3.1 Atmospheric Trace Gas Concentrations

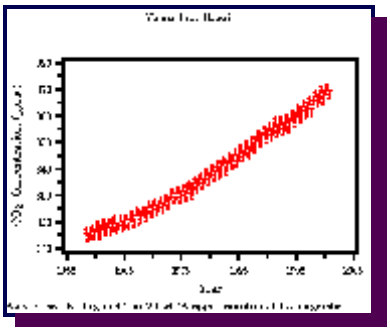
#### 3.3.1.1 Atmospheric $CO_2$ and carbon isotopes

- **Atmospheric $CO_2$ records from sites in the SIO air sampling network**
  *http://cdiac.ornl.gov/trends/co2/sio-keel.htm*

  Contributors: C. D. Keeling and T. P. Whorf (Scripps Institution of Oceanography, University of California)

  Updated by Tom Boden, CDIAC; July 2002.

  Ambient atmospheric $CO_2$ data from the Mauna Loa Observatory; Barrow, Alaska; Cape Matatula, American Samoa; and the South Pole, Antarctic, have been updated with data through 2001.



  The Mauna Loa atmospheric $CO_2$ measurements, which began in 1958, constitute the longest continuous record of atmospheric $CO_2$ concentrations available in the world. The Mauna Loa site is considered one of the most favorable locations for measuring undisturbed air because possible local influences of vegetation or

human activities on atmospheric $CO_2$ concentrations are minimal and any influences from volcanic vents may be excluded from the records. The methods and equipment used to obtain these measurements have remained essentially unchanged during the four-decade-long monitoring program.

The Mauna Loa record shows a 17.4% increase in the mean annual concentration, from 315.98 ppmv of dry air in 1959 to 370.9 ppmv in 2001. The increase in mean annual concentration from 2000 to 2001 was 1.49 ppmv. (The largest single yearly jump in the Mauna Loa record was the 2.87 ppmv increase from 1997 to 1998.)

The annual $CO_2$ concentration at Barrow has risen from 332.8 ppmv in 1974 to 372.3 ppmv in 2001. This represents an annual increase exceeding 1.4 ppmv per year. The Barrow record is considered indicative of maritime air masses and shows the large seasonal amplitude typical of high northerly latitude sites.

At Cape Matatula, the annual average concentration of $CO_2$ rose from 340.6 ppmv in 1982 to 369.8 ppmv in 2001. This represents an annual growth rate of ~1.4 ppmv per year at American Samoa.

The SIO $CO_2$ record from the South Pole shows that annual averages of atmospheric $CO_2$ concentrations rose from 314.8 ppmv in 1958 to 368.1 ppmv in 2000, representing an annual increase over 1.2 ppmv per year.

The Mauna Loa data are also available in NDP-001.

- **Atmospheric $CO_2$ record from continuous measurements at Jubany Station, Antarctica** *http://cdiac.ornl.gov/trends/co2/jubany.htm*

  Contributors: Luigi Ciattaglia and Claudio Rafanelli (CNR-IFA, Rome, Italy); Marcelo Lombardo and Jorge Araujo (DNA-IAA, Argentina)

  Updated by Tom Boden, CDIAC; August 2002.

  CDIAC has updated atmospheric CO2 data from Jubany Station, Antarctica (*http://cdiac.ornl.gov/trends/co2/jubany.htm*) through December 2001. The data were contributed by Luigi Ciattaglia and Claudio Rafanelli (CNR-IFA, Rome, Italy) and Marcelo Lombardo and Jorge Araujo (DNA-IAA, Buenos Aires, Argentina) and prepared for online distribution by Tom Boden. Jubany Station (62° 14'S, 58° 40'W) is situated on King George Island, in the South Shetland archipelago north of the Antarctic Peninsula. The data extend from March 1994 through December 2001. Annual averages have risen from 356.75 ppmv in 1994 to 368.22 ppmv in 2001. The general deceleration of the $CO_2$ growth rate observed during 1997 ! 1998 at Jubany (and other Antarctic stations) seems related to the 1997–1998 El Niño and subsequent La Niña episodes.

### 3.3.2 Climate

#### 3.3.2.1 Temperature

- **A Databank of Antarctic Surface Temperature and Pressure Data (NDP-032)**

*http://cdiac.ornl.gov/epubs/ndp/ndp032/ndp032.html*

Contributors: P. D. Jones and P. A. Reid (University of East Anglia, Norwich, United Kingdom)

Updated by Dale Kaiser, CDIAC, October 2001.

This database contains monthly mean surface temperature and mean sea level pressure data from 29 meteorological stations within the Antarctic region. The first version of this database was compiled at the Climatic Research Unit of the University of East Anglia, Norwich, United Kingdom. The database extended through 1988 and was made available in 1989 by CDIAC as NDP-032. This update of the database includes data through early 1999 for most stations (through 2000 for a few), and also includes all available mean monthly maximum and minimum temperature data. For many stations this means that over 40 years of data are now available, enough for many of the trends associated with recent warming to be more thoroughly examined. Much of the original version of this dataset was obtained from the World Weather Records (WWR) volumes (1951!1970), Monthly Climatic Data for the World (since 1961), although several other sources were also used. Updating the station surface data involved requesting data from countries who have weather stations on Antarctica. Of particular importance within this study are the additional data obtained from Australia, Great Britain, and New Zealand.

Recording Antarctic station data is particularly prone to errors. This is mostly due to climatic extremes and their effects on weather instruments, the nature of Antarctic science, and the variability of meteorological staff at Antarctic stations (high turnover and sometimes untrained meteorological staff). For this compilation, as many sources as possible were contacted to obtain as close to official "source" data as possible. Some error checking has been undertaken, and, hopefully, the final result is as close to a definitive database as possible.

- **Monthly Surface Air Temperature Time Series Area-Averaged Over the 30-degree Latitudinal Belts of the Globe** *http://cdiac.ornl.gov/trends/temp/lugina/lugina.html*

  Contributors: K. M. Lugina (Department of Geography, St. Petersburg State University, Russia) P. Ya. Groisman (National Climate Data Center, Asheville, North Carolina); K. Ya. Vinnikov (University of Maryland); V. V. Koknaeva, and N. A. Speranskaya (State Hydrological Unit, St. Petersburg, Russia)

  Updated by Daria Scott and Dale Kaiser, CDIAC; August 2002.

  The data, graphs, and associated documentation were prepared for online publication by Daria Scott, a summer intern at CDIAC from St. Cloud State University (Minnesota). The update of this database extends its records through 2001, which is now the second warmest year observed in terms of a global average. Temperature anomaly time series since 1881 are included for the "globe" (actually 90EN to 60ES), the Northern Hemisphere, the "Southern Hemisphere" (0-60ES), the latitude band 60ES!90ES (beginning in 1957), and five other 30-degree latitude bands. These include annual and seasonal series for all regions. The present update of the series through 2001 shows that the Northern Hemisphere has warmed at a rate of 0.63EC/100 yrs, and the Southern Hemisphere (0ES!60ES) at a rate of 0.54EC/100 yrs. The warming rate for the globe (in this case, 90EN!60ES) is slightly less than 0.6EC/100 yrs (0.59EC/100 yrs). This trend is very close to that calculated in other recent studies (e.g., Jones et al. 2001, see *http://cdiac.ornl.gov/trends/temp/jonescru/jones.html*). In the global record, the ten warmest years

have all occurred since 1987. In descending order they are 1998, 2001, 1999, 1995, 1990, 2000, 1997, 1991, 1988, and 1987.

- **Global and Hemispheric Temperature Anomalies–Land and Marine Instrumental Records**
  *http://cdiac.ornl.gov/trends/temp/jonescru/jones.html*

  Contributors: P. D. Jones, D. E. Parker, T. J. Osborn (University of East Anglia, United Kingdom); and K. R. Briffa (Hadley Centre for Climatic Prediction and Research, United Kingdom)

  Updated by Dale Kaiser and Daria Scott, CDIAC; November 2001.
  These data, updated to include data through 2000, were corrected for nonclimatic effects, such as station shifts and instrument changes. The resulting data set has been used extensively in various Intergovernmental Panel on Climate Change (IPCC) reports, and the global-mean temperature changes evident in the record have been interpreted in terms of anthropogenic forcing influences and natural variability. Trends in annual mean temperature anomalies for the globe show relatively stable temperatures from the beginning of the record through about 1910, with relatively rapid and steady warming through the early 1940s, followed by another period of relatively stable temperatures through the mid-1970s, then another rapid rise similar to that earlier in the century. The 2000 global mean temperature anomaly was +0.29EC above the 1961!1990 mean temperature. This is somewhat cooler than the anomalies of the previous three years, but 2000 still ties with 1991 as the sixth warmest year in the global record, and the eight warmest years of the global record have all occurred since 1990. These are, in descending order, 1998, 1997, 1995, 1990, 1999, (2000 and 1991 - tie), and 1994.

- **Global, Hemispheric, and Zonal Temperature Deviations Derived from Radiosonde Records**
  *http://cdiac.ornl.gov/trends/temp/angell/angell.html*

  Contributors: James Angell (NOAA Air Resources Laboratory, Silver Spring, Maryland)

  Updated by Sonja Jones and Dale Kaiser, CDIAC; April 2002.

  Based on data from Angell's global network of 63 radiosonde stations, over the period from 1958 through 2001, the global mean, near-surface air temperature warmed by approximately 0.15°C/decade (calculated by means of least-squares, linear regression). This is about 0.01°C/decade greater than the trend reported in Angell (1999) for the period 1958!1999. The 850-300 mb tropospheric layer warmed by about 0.08°C/decade over 1958!2001. This is about 0.02EC/decade less than that published for 1958!1999 in Angell (1999). The global mean 300-100 mb tropopause layer temperature cooled by approximately -0.2°C/decade, driven mainly by large changes in the Polar zones, and the 100-50 mb low-stratospheric layer experienced a global-mean cooling of about -0.6EC/decade. At both the surface and in the troposphere, 1998 was the warmest year of the 44-year record, but when the influence of the powerful El Niño of 1997!1998 on tropospheric temperature is taken into account, 1990 remains the warmest year of the record (Angell 2000).

### 3.4. Newsletters, Reports, and Additional Online Publications

- ***CDIAC Communications.*** **Issue Number 29**

*http://cdiac.ornl.gov/newsletr/march2002/cc29.pdf*

Edited by Sonja Jones, CDIAC; March 2002.

CDIAC published the Spring 2002 issue (#29) of CDIAC's newsletter, *CDIAC Communications*. This issue featured the lead story, "My First Antarctic Cruise," and described CDIAC researcher Alex Kozyr's oceanographic expedition to Antarctica. The newsletter also lists new and updated global-change data and information products made available since Issue #28 and provides information relevant to CDIAC's Focus Area Outreach (i.e., AmeriFlux, NARSTO, Oceans, FACE).

- ***Fiscal Year 2001 Annual Report*** **(ORNL/CDIAC-137)**
  *http://cdiac.ornl.gov/epubs/cdiac/cdiac137/2001annrpt.html*

  Contributors: Robert M. Cushman, Thomas A. Boden, Leslie A. Hook, Sonja B. Jones, Dale P. Kaiser, Alexander Kozyr, and Tommy Nelson, CDIAC

  Prepared by Carolyn Householder, CDIAC; May 2002.

  The report documents highlights from the fiscal year (new data products and other publications) and provides information on CDIAC, which includes the World Data Center for Atmospheric Trace Gases. The report provides information of relevance to CDIAC focus areas (e.g., AmeriFlux, NARSTO, FACE, Oceans); provides statistics, such as the number of requests for global change data and information from CDIAC and citations in the published literature of data obtained from CDIAC; alerts users to new data products (publications and databases) that CDIAC hopes to release in the new fiscal year; lists awards received by CDIAC and publications and presentations of its staff; lists the many organizations with which CDIAC has collaborated to produce the data and information products it released in the current fiscal year; a staff listing; and an acronym and abbreviation list.

- ***Graduate Student Theses Supported by DOE's Environmental Sciences Division: Fiscal Year 2001 Update*** **(ORNL/CDIAC-136)** *http://cdiac.ornl.gov/epubs/cdiac/cdiac136/cdiac136.html*

  Updated by Bob Cushman, CDIAC; February 2002.

  This document updates the 1995 report, *Graduate Student Theses Supported by DOE's Environmental Sciences Division* (DOE/ER-0649T), and the 2000 update, providing complete bibliographic citations, abstracts, and keywords for doctoral and master's theses published in late 2000 and 2001, and supported fully or partly by DOE's Climate Change Research Division through the National Institute for Global Environmental Change (NIGEC). Information on the major professor, department, principal investigator, and program area is given for each abstract.

- **Publications, Presentations, and Awards (ORNL/CDIAC-101)**
  *http://cdiac.ornl.gov/epubs/cdiac/cdiac101/pubslist.htm*

  Updated by Bob Cushman, CDIAC; December 2001.

Bob Cushman updated the online listing of CDIAC's "Publications, Presentations, and Awards" ORNL/CDIAC-101 (*http://cdiac.ornl.gov/epubs/cdiac/cdiac101/pubslist.htm*).

### 3.5 What's Coming in FY 2003

CDIAC is currently working on, or has completed, the following new or existing data and information products for FY 2003.

- Area and Carbon Content of Sphagnum Since Last Glacial Maximum. *Added October 2002.*
- Current Greenhouse Gas Information ! Revised and updated! *Updated October 2002.*
- Carbon Flux to the Atmosphere from Land-Use Changes. *Added October 2002.*
- CDIAC announces its new World Directory User Interface. This web-accessible interface allows CDIAC data users to add themselves or modify their existing record in the CDIAC World Directory. E-mail validation is routine for user modification. CDIAC also provides a "blind" e-mail service to facilitate consensual communication between researchers, educators, students, and others sharing a common interest in global climate change. *Added November 2002*.
- Carbon Dioxide, Hydrographic and Chemical Data Obtained During the Nine R/V *Knorr* Cruises Comprising the Indian Ocean $CO_2$ Survey (WOCE Sections I8SI9S, I9N, I8NI5E, I3, I5WI4, I7N, I1, I10, and I2; December 1, 1994 ! January 22, 1996) (ORNL/CDIAC-138, NDP-080). *Added November 2002*.
- The ALE/GAGE/AGAGE Network (DB1001). *Updated December 2002.*
- Atmospheric $CO_2$ Concentrations from the CSIRO GASLAB Flask Sampling Network. *Added December 2002.*
- Atmospheric $CH_4$ concentrations from sites in the CSIRO Atmospheric Research GASLAB air sampling network. *Added January 2003*.
- Atmospheric CO Concentrations from the CSIRO GASLAB Flask Sampling Network Historical $CO_2$ record from the Vostok ice core. *Added February 2003*.
- FACTS II (Rhinelander, Wisconsin) FACE $CO_2$ Data. *Added February 2003*.
- Cloud Climatology for Land Stations Worldwide, 1971 ! 1996 (NDP-026D). *Added March 2003.*
- Atmospheric $H_2$ Concentrations from the CSIRO GASLAB Flask Sampling Network. *Added March 2003.*
- Publications, Presentations, and Awards (CDIAC-101). *Updated March 2003*.
- CSIRO GASLAB Network: Individual Flask Measurements of Atmospheric Trace Gases (DB1021). *Added April 2003.*
- Terrestrial Carbon Sequestration databases *Added May 2003.*
- Measurements of $CH_4$ mixing ratio and D/H and $^{13}C/^{12}C$ isotope ratios in atmospheric samples from two sites in the United States (DB1022). *Added May 2003*.
- Comparison of Inorganic Carbon System Parameters Measured in the Atlantic Ocean from 1990 to 1998 and Recommended Adjustments (CDIAC-140). *Added June 2003.*
- Estimates of Monthly $CO_2$ Emissions and Associated $^{13}C/^{12}C$ Values from Fossil-Fuel Consumption in the U.S.A. *Added June 2003*.
- GLODAP Atlantic Ocean Atlas for carbon-related parameters. *Added June 2003*.
- Estimates of Monthly $CO_2$ Emissions and Associated $^{13}C/^{12}C$ Values from Fossil-Fuel Consumption in the U.S.A. *Added June 2003.*
- ORNL FACE LAI data sets. *Added June 2003*.

CDIAC continually expands *Trends Online* with new records and updates to existing records. Remember to check the "New" page on our Web site (*http://cdiac.ornl.gov/new/new.html*) for announcements of the latest CDIAC data and information products.

# 4. Information Services

## 4.1 FY 2002 Statistics

Statistics reflecting CDIAC's FY 2002 Web activity were calculated using data generated by the Sane Solutions, LLC, Web log analysis tool, NetTracker®. While CDIAC continues to receive and respond to users via the traditional means (i.e., email, mail, fax, telephone, etc.), users also continue to access data products through direct FTP. Although FTP data transfers were recorded in FY 2002, statistics in these areas are minuscule in comparison to statistics generated from CDIAC's Web site activity.

In FY 2002, more than 280,000 unique hosts visited CDIAC's Web site (Figure 4.1) utilizing 307 browsers. The browsers of choice were the various versions of Microsoft Internet Explorer, Netscape Navigator, and America Online, respectively.

During FY 2002, CDIAC's Web site received more than 531,000 visits with users viewing over 3,109,000 Web pages. The average number of pages accessed per day in FY 2002 was 8,900. The average length of a visit to CDIAC's Web site was 19 minutes. FY 2002 statistics show a 20% increase in CDIAC Web traffic over FY 2001. Because visits and views are calculated using some CDIAC-specified indicators (e.g., starting time, length of visit, machine IP addresses), these figures are considered estimates. (See Figure 4.2 for explanation of views and visits.)

Visits to CDIAC's Web site were made from 120 different domains (Figure 4.3) with the top domain being the U.S. commercial sector. Of these 120 domains, 111 domains represented hosts from foreign countries (Figure 4.4).

Net Tracker® was used to analyze the hosts and their individual paths (path being defined as the first three consecutive pages viewed by a Web site visitor) on the CDIAC Web site. The analysis indicates that users entering the CDIAC Web site accessed CDIAC major keywords used to locate CDIAC data and information products via online search engines (e.g., Yahoo, google.com, AltaVista, msn.com, Excite, Lycos, netscape.com). The major keywords are:

- carbon dioxide,
- greenhouse effect,
- carbon,
- CO2,
- cdiac,
- carbon dioxide emissions, and
- global warming.

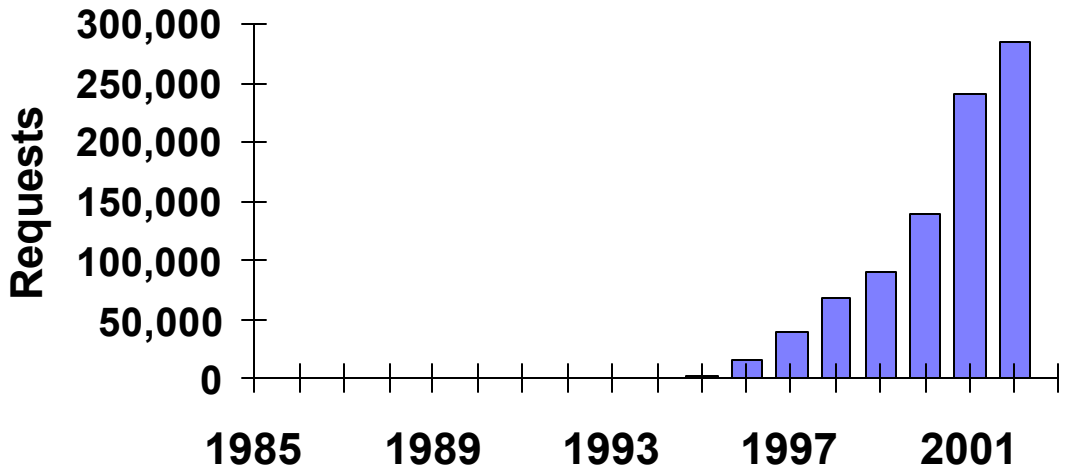



**Figure 4.1 Web-Based Request Activity, FY 1985 - FY 2002.**

CDIAC's audience of worldwide users includes:

- educators (teachers, professors),
- students (elementary, high school, college graduate and undergraduate),
- general public (interested citizens, special interest groups),
- specialists (scientists, engineers, business and industry),
- government (legislative assistants, policymakers, agencies), and
- media (radio, television, newspapers).

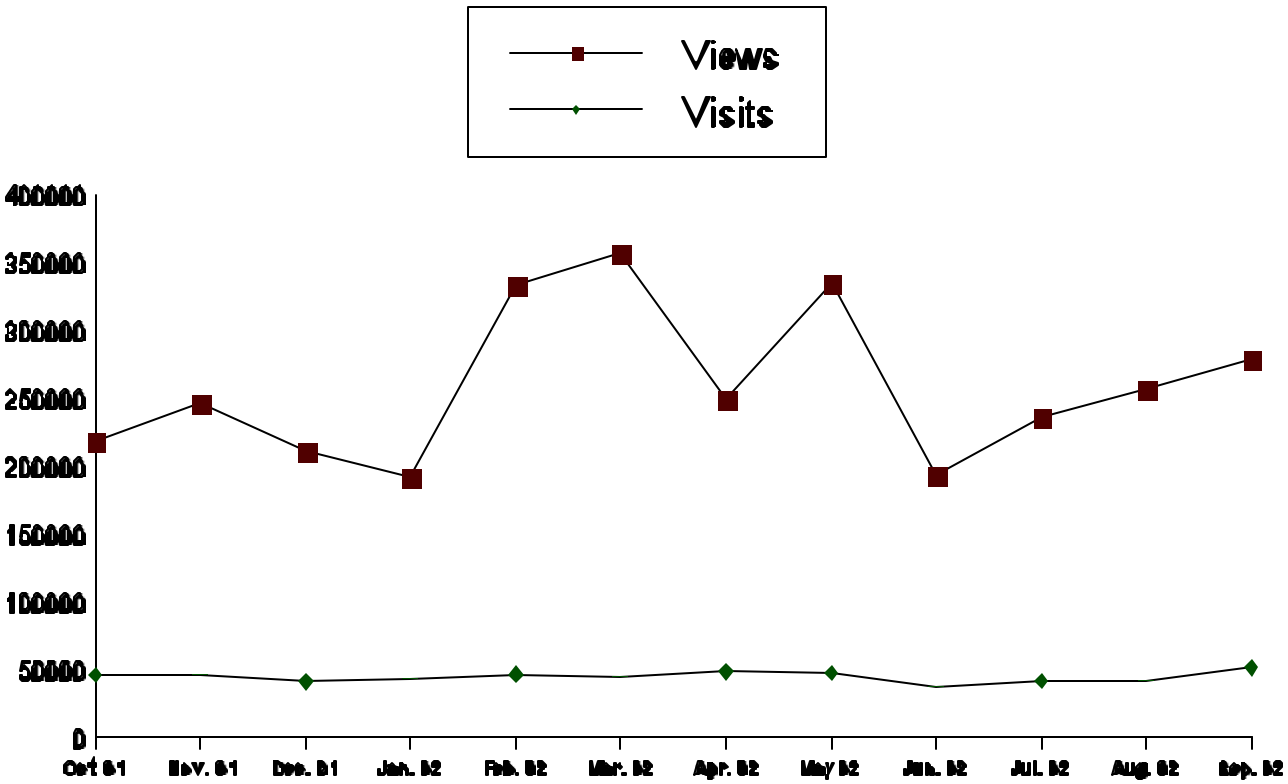



**Figure 4.2 Comparison of Views/Visits for FY 2002.**

NOTE:

- A view is defined by NetTracker® as a hit to a Web page, excluding user-defined files (CDIAC excludes such files as .jpg, .gif, etc.).
- A visit is defined as a series of consecutive views of a Web site by the same unique host within a specified period of time.

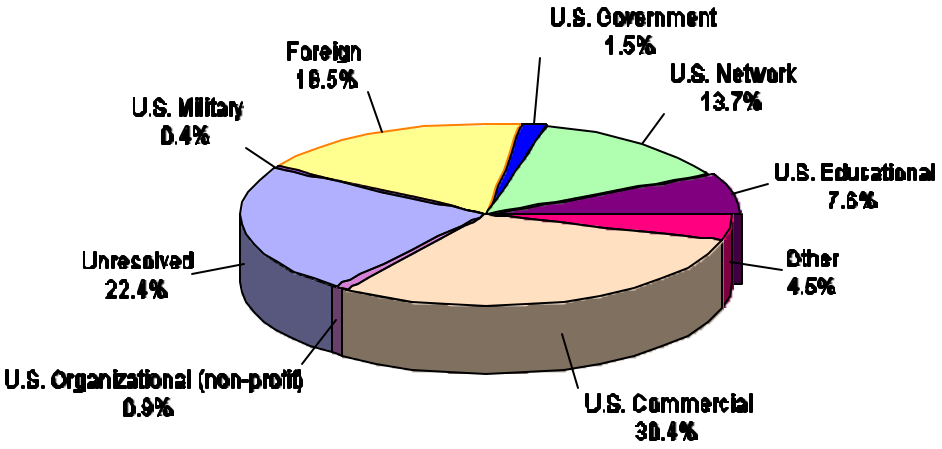



**Figure 4.3 Analysis of Web Site Visits by User Domain.**

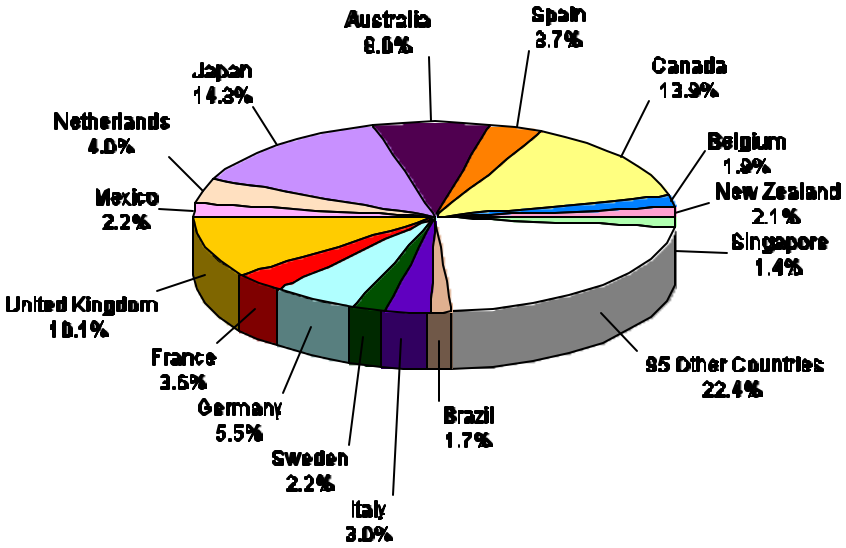



**Figure 4.4 Analysis of Web Site Visits Representing Foreign Countries.**

# 5. Computer Systems Development

CDIAC's computer systems development team continues to search for ways to improve our operation and increase efficiency. To keep pace with the proliferation of data and increasing global interest in climate change data, we must continue to anticipate the impact of emerging information technologies and position ourselves to apply those technologies to meet the needs of our global user community.

## 5.1 Infrastructure Improvements

We added nearly 500 gigabytes of shared RAID 5 storage to the CDIAC computing system network. We will migrate data holdings from older disk storage systems, nearing the end of their life cycle, to this new medium.

## 5.2 LAS Server

We procured the hardware necessary to implement a stand-alone Live Access Server (LAS) at CDIAC. The new server is comprised of a Dell PowerEdge 1650 rack mounted server and 200 gigabytes of RAID storage. The LAS is a highly configurable Web server designed to provide flexible access to geo-referenced scientific data. It can present distributed data sets as a unified virtual database through the use of Distributed Oceanographic Data System (DODS) networking. Ferret is LAS's default visualization application, but applications such as Matlab, IDL, and GrADS can also be used. The LAS enables the Web user to visualize data via dynamic graphics, request custom subsets of data in a variety of file formats, access metadata describing the data, and compare variables from disparate locations. LAS enables the data provider to provide access to multiple types of data via a single interface, create thematic data servers from distributed data sources, offer dynamic derived products, address metadata inadequacies, and offer coupled visualization products. The initial LAS implementation will provide access to CDAIC's GLODAP data holdings.

## 5.3 World Directory User Interface

Since its inception in 1982, CDIAC has maintained a directory of users in order that we may easily provide information regarding new products, updates, and corrections as necessary. Information contained in the CDIAC World Directory has been voluntarily provided by users and is not distributed to any other agencies or individuals.

In 2002, we completed development of a new service to allow users to add their information to the directory, or modify their existing information as contained in the directory. Because we verify and confirm all additions or changes to the directory, only users with a valid e-mail of record are permitted to modify their information via the Web. As part of this feature, we also provide a blind e-mail service to facilitate consensual communication between researchers, educators, students, and others sharing this common interest. The public features of the system are accessible by selecting "Directory" on the CDIAC home page.

The system also provides an exclusive set of CDIAC staff functions previously accomplished via the Request Response Record (R3) system. These functions, available only to CDIAC staff, allow the user to perform extensive ad-hoc queries of the data and perform data modifications without requiring specific knowledge of

the underlying data structure or Structured Query Language (SQL) language. The system also provides CDIAC staff with the capability to generate mailing labels and lists via Microsoft Access® and Open Database Connectivity (ODBC) drivers. This functionality will allow us to remove the long-lived R3 system from production.

### 5.4 CDIAC Implementation of Mercury

We completed the CDIAC implementation of Mercury. Mercury, developed at ORNL, is a data search-and-retrieval system that utilizes metadata to perform very accurate searches. Mercury provides our users with sophisticated data search tools, including browse trees and dynamic pick lists. In addition to these tools, the CDIAC implementation of Mercury provides tools to perform spatial and temporal data searches. Mercury offers but one example of the benefits to be derived from implementation of CDIAC's new metadata standard. The CDIAC prototype system was completed, and beta testing was initiated. Testing of the CDIAC implementation of Mercury brought to light inconsistencies in the metadata that reduce the usefulness of the system. Resolving these relatively minor inconsistencies will greatly enhance the benefit derived by the user community. While relatively minor, correcting the metadata inconsistencies is labor-intensive. We held back public release of the CDIAC implementation of Mercury pending these metadata modifications. At the time of this report, metadata modifications to existing files were ongoing.

### 5.5 CDIAC ORNL Metadata Editor (OME) Tools

There are many new, rapidly developing information management tools designed to help users accurately locate pertinent data while eliminating extraneous information. These tools, typically based on XML (eXtensible Markup Language), require complete and accurate metadata to be useful. Last year, we worked with DAAC staff to develop a tool for CDIAC based on the ORNL Metadata Editor (OME). This tool, the CDIAC OME, expedites metadata generation by providing user-friendly metadata collection forms for the input and modification of metadata, via a dynamic interface. During FY 2002, several new OME modifications were completed. The OME is now accessible to all CDIAC staff and is being utilized to make enhancements to the metadata files for CDIAC data products. We encourage staff to keep product metadata current and to create proper metadata, via the OME, as new products are developed. These .xml metadata files will make CDIAC data much more visible through Internet indexing services and will improve the accuracy of those services.

### 5.6 SAS Upgrade

CDIAC staff utilizes SAS software, among other tools, to perform quality assurance and analysis of CDIAC datasets. We upgraded our SAS software suite from version 6.12 to version 8.1. SAS version 8.1 is a major new release offering many new capabilities and enhancements. Among these upgrades are support for longer dataset names; the Output Delivery System (ODS); new statement options; Audit Trail; enhancements to SAS/GRAPH®, SAS/STAT®, SAS/ACCESS®, SAS Data Libraries, and Proc Access; and new IMPORT/EXPORT functions.

### 5.7 Computer Systems Maintenance and Updates

We also spent a considerable amount of time performing necessary routine functions in support of the CDIAC Computing System Network. These tasks included nightly backups, upgrading/replacing disk drives, creating

new file systems, installing/upgrading application software and operating system enhancements, restoring user-deleted files, installing/replacing an uninterruptible power supply (UPS), responding to a wide variety of CDIAC staff calls for help, producing Web statistics, making wholesale Web changes, providing Web design direction, and maintaining Web servers and the Web development area.

### 5.8 Carbon Sequestration Web Server

We continue to operate the server for the Carbon Sequestration Web site, at the request of DOE program management. In FY 2002, this Sun workstation based system received over 90,000 requests and averaged 250 visits per day from 45 countries around the world.

### 5.9 Plans for FY 2003

Based on system improvements implemented at CDIAC, we continue to take full advantage of evolving computing and information management technologies. We have plans to build upon several new information management tools under continuing development at ORNL. We are excited by what these tools will offer our user community and look forward to a productive year in FY 2003.

We will complete installation and configuration of the LAS. The LAS is a highly configurable Web server application designed to provide flexible access to geo-referenced scientific data. The new server, comprised of a Dell PowerEdge 1650 rack mounted server and 200 gigabytes of RAID storage, will run LAS under the Red Hat Linux operating system.

We will implement a public version of the CDIAC version of Mercury. Mercury, developed at ORNL, is a data search and retrieval system that utilizes metadata to perform very accurate searches. Mercury will provide our users with sophisticated data search tools, including browse trees and dynamic pick lists. In addition to these tools, the CDIAC version of Mercury will provide tools to perform spatial and temporal data searches. Along with metadata enhancements currently under way, this system will greatly improve our user community's access to CDIAC products.

Subject to budget constraints, we will replace a couple of desktop systems that have proven problematic. It is apparent that it will be cost-effective to replace these systems with more reliable hardware.

The current version of NetTracker, the software we use to track Web usage, must be updated to remain compliant with operating system upgrades. Because of dramatic increases in the cost of this product, and our need for improved functionality, we plan to evaluate alternatives to NetTracker before replacing our current Web log analysis software.

# 6. CDIAC Presentations, Publications, and Awards

## 6.1 Presentations

- Alex Kozyr attended the CARINA *(http://www.ifm.uni-kiel.de/fb/fb2/ch/research/carina/)* Project Steering Committee Meeting (Las Palmas, Canary Islands) for discussions on completion of the Atlantic Ocean data collection and the future of CARINA, including possible collaboration with PICES, the North Pacific Marine Science Organization. CDIAC plays an important data management role in both CARINA and PICES (see *http://cdiac.ornl.gov/oceans/home.html*). September 2002.
- Gregg Marland visited RIVM, the National Institute of Public Health and Environment (Utrecht, The Netherlands), and presented a seminar on net greenhouse gas impacts of carbon sequestration. CDIAC and RIVM collaborate on global inventories of emissions of greenhouse gases; discussions focused on achieving finer spatial and temporal resolution in emissions estimates, and on accounting properly for the oxidation of the carbon in long-lived products derived from petroleum. September 2002.
- Gregg Marland presented the seminar "In Carbon, Out Carbon; My Carbon, Your Carbon, Who is Responsible for Global Climate Change?" at Ohio State University (OSU), the second OSU Environmental Research Distinguished Lecture. (The first speaker in this prestigious new lecture series was Robert Watson, former chairman of the Intergovernmental Panel on Climate Change.) June 2002.
- Gregg Marland participated in a workshop on "Improving the Linkages Between Carbon Cycle Models and Integrated Assessment Models" (Princeton University) as a member of the panel discussing "What can social scientists (not just IAM modelers) provide to carbon cycle modelers?". May 2002.
- T. J. Blasing presented "Global Warming: Hot Air and Cold Facts" at the March meeting of the American Meteorological Society's Smoky Mountain Chapter (Knoxville, Tennessee). The talk began with the basic physical chemistry underlying the radiative properties of greenhouse gases and the observed increases in atmospheric concentrations of greenhouse gases, then proceeded to the more controversial topic of how they might be related to the observed warming of the lower atmosphere. March 2002.
- Bob Cushman presented "Adding Value to Global-Change Data" at the Olga G. Nalbandov Symposium, "New Frontiers in Biocomplexity and Biodiversity," held at the University of Illinois, Urbana-Champaign (*http://www.life.uiuc.edu/plantbio/symposium/*). He stressed the importance of satisfying the needs of both data providers (especially maintaining intellectual property rights) and data users (locating, obtaining, and understanding the data) in a successful data management operation. February 2002.
- CDIAC summer student Daria Scott (St. Cloud State University, Minnesota) presented the paper, "Evidence for a recent advance in the timing of a surface-air warming singularity in late winter over the north central United States," co-authored with T. J. Blasing and Dale Kaiser, at the American Meteorological Society's 13th Symposium on Global Change and Climate Variations (Orlando, Florida). The paper concludes that "termination of winter" tends to show up earlier in 1976 ! 1999 than it does in 1952 ! 1975, although it is not clear whether this is a response to global warming or part of a natural oscillation in the earth-atmosphere system. January 2002.

## 6.2 Publications

- CDIAC put data online summarizing the effects of crop rotation and tillage practices on soil carbon sequestration rates(*http://cdiac.ornl.gov/programs/CSEQ/terrestrial/westpost2002/westpost 2002. html*). The data, provided by Tris West and Mac Post (DOE Center for Research on Carbon

Sequestration in Terrestrial Ecosystems and ORNL Environmental Sciences Division), and prepared for online distribution by Bob Cushman, are from a paper that will soon appear in the *Soil Science Society of America Journal.* August 2002.

- Dale Kaiser, Daria Scott (CDIAC summer intern from St. Cloud State University in Minnesota), Sonja Jones, Kevin Birdwell, and Ron Walli of the ORNL Communications and Community Outreach Office produced a seasonal story about trends in July 4 high temperatures throughout the United States since 1960. A few cities have seen significant warming trends on July 4 over the past four decades (Knoxville/Oak Ridge, Tennessee, area; Chicago, Illinois, area), while the Seattle, Washington, area has seen a cooling trend. The rest of the 21 stations in the study showed no significant trends. The story was picked up by the Associated Press and appeared in several newspapers, including the *Knoxville News-Sentinel*, the *Oak Ridger* (*http://www.oakridger.com/stories/070402/new_0703020081.html*), and the *Columbia (Tennessee) Daily Herald*. The ORNL Communications and Community Outreach Office viewed this effort as a human interest story, and ORNL researchers were careful to point out that these results cannot be interpreted as an indicator of climate variability in broader terms. July 2002.
- The paper "Data and Metadata Reporting Standards for the U.S. Environmental Protection Agency's PM Supersites Research Program," presented in April at the 21st Annual National Conference on Managing Environmental Quality Systems (Phoenix, Arizona), is now online at EPA's Quality Web site (see page 139 in *http://www.epa.gov/quality1/qs-docs/21qa-papers.pdf*). The paper was authored by CDIAC's Les Hook and Sig Christensen with Bill Sukloff (Environment Canada, Meteorological Service of Canada). June 2002.
- Dale Kaiser, along with Ron Walli of the ORNL Communications and Community Outreach Office and former CDIAC employee, Kevin Birdwell (now with the ORNL Computational Sciences and Engineering Division), and assisted by Bob Cushman and Sonja Jones, produced a seasonal story about trends in occurrence of a "White Christmas" throughout the United States since the 1960s. The story was run by media both large (CNN, The Washington Post, The Dallas Morning News, The Detroit Free Press, The Atlanta Journal-Constitution, and The Seattle Times) and small (WSJM in St. Joseph, Michigan). December 2001.
- The article "The Relative Importance of Sources of Greenhouse-Gas Emissions, Comparison of Global Through Subnational Perspectives," by Bob Cushman and Sonja Jones, was published in Volume 29, No. 3, of the journal *Environmental Management* (*http://link.springer.de/link/service/journals/00267/bibs/2029003/20290360.html*). This paper analyzes greenhouse-gas emissions from the many individual sources, on scales ranging from global to national to state. Individual country and state perspectives exhibit some commonalities but differ among themselves and, from a global-scale perspective, in detail. February 2002.
- Alex Kozyr co-authored (with M. F.Lamb, et al.) the paper "Consistency and synthesis of Pacific Ocean $CO_2$ survey data," which appeared in the journal *Deep-Sea Research II*, volume 49, pages 21!58 (2002), available online at: *http://sciserver.lanl.gov/cgi-bin/sciserv.pl?collection=journals&journal=09670645&issue=v49i1-3&article=21_casopocsd*. January 2002.

### 6.3 Awards and Kudos

- CDIAC's "Trends Online: A Compendium of Data on Global Change" (*http://cdiac.ornl.gov/trends/trends.htm*) received the Merit Award for Online Books in the 2002 competition of the East Tennessee Chapter of the Society for Technical Communication (*http://www.stc-etc.org/*).

- CDIAC was invited to join the Expert Team on Data Archival and Access for the Data Management and Communications subsystem of the Sustained Integrated Ocean Observing System (IOOS). The IOOS is a "national and international network that systematically acquires and disseminates data and products in response to the needs of government agencies, industries, scientists, educators, nongovernmental organizations, and the public." July 2002.
- CDIAC's Alex Kozyr has been named a member of Working Group 17 (Biogeochemical Data Integration and Synthesis) of PICES (the North Pacific Marine Science Organization; *http://pices.ios.bc.ca/*), along with researchers from Canada, Japan, Korea, Russia and the United States. January 2002.


- "In appreciation of CDIAC's 20 years of service as the U.S. Department of Energy's premier center for global change data and information," an appreciation award was presented to CDIAC in FY 2002 by Raymond L. Orbach, Director, Office of Science. "During this time, CDIAC set the standard for quality-assuring and documenting key global-change data bases, and provided this information to a diverse user community of researchers, educators, students, government and corporate officials, the media and the interested lay public." April 2002.

# 7. Selected CDIAC Citations

The following citations are examples of how CDIAC products are used and cited.

*NDP-050 (Houghton and Hackler)*

United Nations Environment Programme. 2002. *Global Environment Outlook 3 Data Compendium.* Nairobi, Kenya.

*NDP-067 (Koertzinger et al.)*

Bender, M., S. Doney, R. A. Feely, I. Fung, N. Gruber, D. E. Harrison, R. Keeling, J. K. Moore, J. Sarmiento, E. Sarachik, B. Stephens, T. Takahashi, P. Tans, and R. Wanninkhof. 2002. *A Large-Scale $CO_2$ Observing Plan: In Situ Oceans and Atmosphere (LSCOP)*. National Oceanic and Atmospheric Administration, Office of Global Programs, Silver Springs, Maryland.

*NDP-070 (Easterling et al.)*

Scott, D., T. J. Blasing, and D. P. Kaiser. 2002. Evidence for a recent advance in the timing of a surface-air warming singularity in late winter over the north central United States, pp. 73!76, in *Proceedings, 13th Symposium on Global Change and Climate Variations*. American Meteorological Society, Boston, Massachusetts.

*NDP-076 (Goyet et al.)*

Lamb, M. F., C. L. Sabine, R. A. Feely, R. Wanninkhof, R. M. Key, G. C. Johnson, F. J. Millero, K. Lee, T.-H. Peng, A. Kozyr, J. L. Bullister, D. GReely, R. H. Byrne, D. W. Chipman, A. G. Dickson, C. Goyet, P. R. Guenther, M. Ishii, K. M. Johnson, C. D. Keeling, T. Ono, K. Shitashima, B. Tilbrook, T. Takahashi, D. W. R. Wallace, Y. W. Watanabe, C. Winn, and C. S. Wong. 2002. Consistency and synthesis of Pacific Ocean $CO_2$ survey data. *Deep-Sea Research II* 49:21!58.

*Trends '93 (ORNL/CDIAC-65) and Trends Online*

Cushman, R. M., and S. B. Jones. 2002. The relative importance of sources of greenhouse-gas emissions: Comparison of global through subnational perspectives. *Environmental Management* 29:360!372.

Langenfelds, R. L., R. J. Francey, B. C. Pak, L. P. Steele, J. Lloyd, C. M. Trudinger, and C. E. Allison. 2002. Interannual growth rate variations of atmospheric $CO_2$ and its ä$^{13}$C, $H_2$, $CH_4$, and CO between 1992 and 1999 linked to biomass burning. *Global Biogeochemical Cycles* 16:1048!1069.

Marland, G., and T. Boden. 2002. The increasing concentration of atmospheric $CO_2$: How much, when, and why?, p.283!295. In *International Seminar on Nuclear War and Planetary Emergencies, 26th Session* (R. Ragaini, ed.). World Scientific, Riveredge (New Jersey), London, Singapore, and Hong

Kong.

Raich, J. W., C. S. Potter, and D. Bhagawati. 2002. Interannual variability in global soil respiration, 1980!94. *Global Change Biology* 8:1!13.

Sarmiento, J. L., and N. Gruber. 2002. Sinks for anthropogenic carbon. *Physics Today* 55(8):30.

United Nations Environment Programme. 2002. *North America's Environment: A Thirty-Year State of the Environment and Policy Retrospective*. Washington, D.C.

United Nations Environment Programme. 2002. *Global Environment Outlook 3 Data Compendium.* Nairobi, Kenya.

*ORNL/CDIAC-74 (Dickson and Goyet, eds.)*

Gruber, N., C. D. Keeling, and N. R. Bates. 2002. Interannual variability in the North Atlantic Ocean carbon sink. *Science* 298:2374!2378.

*ORNL/CDIAC-105 (Lewis and Wallace)*

Lamb, M. F., C. L. Sabine, R. A. Feely, R. Wanninkhof, R. M. Key, G. C. Johnson, F. J. Millero, K. Lee, T.-H. Peng, A. Kozyr, J. L. Bullister, D. GReely, R. H. Byrne, D. W. Chipman, A. G. Dickson, C. Goyet, P. R. Guenther, M. Ishii, K. M. Johnson, C. D. Keeling, T. Ono, K. Shitashima, B. Tilbrook, T. Takahashi, D. W. R. Wallace, Y. W. Watanabe, C. Winn, and C. S. Wong. 2002. Consistency and synthesis of Pacific Ocean $CO_2$ survey data. *Deep-Sea Research II* 49:21!58.

*ORNL/CDIAC-115 (Feely et al.)*

Lamb, M. F., C. L. Sabine, R. A. Feely, R. Wanninkhof, R. M. Key, G. C. Johnson, F. J. Millero, K. Lee, T.-H. Peng, A. Kozyr, J. L. Bullister, D. GReely, R. H. Byrne, D. W. Chipman, A. G. Dickson, C. Goyet, P. R. Guenther, M. Ishii, K. M. Johnson, C. D. Keeling, T. Ono, K. Shitashima, B. Tilbrook, T. Takahashi, D. W. R. Wallace, Y. W. Watanabe, C. Winn, and C. S. Wong. 2002. Consistency and synthesis of Pacific Ocean $CO_2$ survey data. *Deep-Sea Research II* 49:21!58.

# 8. CDIAC Collaborations

CDIAC realizes that it would not be possible to produce global-change data and information products without the generosity and cooperation of researchers at institutions throughout the United States and around the world. In this annual report, we have noted the collaborating individuals and institutions for each product. Listed below are the many institutions that have collaborated with CDIAC in the publication of the databases and other information products described in this report.

## 8.1 DOE Laboratories

- Brookhaven National Laboratory

## 8.2 Other Federal Agencies

- NOAA Air Resources Laboratory
- NOAA Atlantic Oceanographic and Meteorological Laboratory
- NOAA Climate Monitoring and Diagnostics Laboratory
- NOAA Pacific Marine Environmental Laboratory (PMEL)

## 8.3 Universities/Research Institutions

- Georgia Institute of Technology
- Lamont-Doherty Earth Observatory of Columbia University
- Massachusetts Institute of Technology
- Monterey Bay Aquarium Research Institute
- National Institute for Global Environmental Change (NIGEC) National Office (University of California, Davis)
- Ohio State University
- Oregon Graduate Institute of Science and Technology
- Portland State University
- Princeton University
- Rosenstiel School of Marine and Atmospheric Sciences, University of Miami
- Scripps Institution of Oceanography (SIO), University of California, San Diego
- University of California, Berkeley
- University of Hawaii
- University of Nebraska ! Lincoln
- University of North Dakota
- University of South Florida
- Woods Hole Oceanographic Institution

## 8.4 Foreign Collaborators

- Arctic and Antarctic Research Institute, Russia
- Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia
- Hadley Centre for Climate Prediction and Research, United Kingdom
- Institute of Geography, Russia
- Institute of Ocean Science, Canada
- Instituto Español de Oceanografía, Spain
- International Science Consultants, United Kingdom
- Laboratoire de Glaciologie et Géophysique de l'Environnement, France
- Laboratoire des Sciences du Climat et de l'Environnement, France
- University of East Anglia, United Kingdom

# 9. Acronyms and Abbreviations

| | |
|---|---|
| AGAGE | Advanced Global Atmospheric Gases Experiment |
| ALE | Atmospheric Lifetime Experiment |
| AmeriFlux | Eddy Covariance Flux Network in North, Central, and South America |
| CARDS | Comprehensive Aerological Reference Data Set |
| CARINA | CARbon dioxide In the North Atlantic ocean |
| CAS | Chemical Abstracts Service |
| CDIAC | Carbon Dioxide Information Analysis Center |
| CFCs | chlorofluorocarbons |
| CMP | computer model package |
| $CO_2$ | carbon dioxide |
| CSIRO | Commonwealth Scientific and Industrial Research Organisation |
| CTD | conductivity, temperature, and depth |
| DAAC | Distributed Active Archive Center |
| DB | database |
| DES | Data Exchange Standard |
| DIST | Data and Information Sharing Tool |
| *DMHB* | *Data Management Handbook* |
| DODS | Distributed Oceanographic Data System |
| DOE | U.S. Department of Energy |
| EC | eddy covariance |
| EPA | U.S. Environmental Protection Agency |
| ESD | Environmental Sciences Division |
| FACE | Free-Air $CO_2$ Enrichment |
| FAO | Food and Agriculture Organization |
| FTP | File Transfer Protocol |
| FY | fiscal year |
| GAGE | Global Atmospheric Gases Experiment |
| GCDIS | Global Change Data and Information System |
| GLODAP | GLobal Ocean Data Analysis Project |
| GTS | Global Telecommunications System |
| HTML | Hypertext Markup Language |
| IOOS | Sustained Integrated Ocean Observing System |
| IPCC | Intergovernmental Panel on Climate Change |
| IRGA | Infrared Gas Analyzers |
| JGOFS | Joint Global Ocean Flux Study |
| JODC | Japan Oceanographic Data Center |
| LAI | leaf area index |
| LAS | Live Access Server |
| MEDS | Marine Environmental Data Service (Canada) |
| Mg | Megagram |
| MODIS | moderate-resolution imaging spectro-radiometer |

| | |
|---|---|
| MSU | microwave sounding unit |
| NARSTO | *formerly* North American Research Strategy for Tropospheric Ozone |
| NASA | National Aeronautics and Space Administration |
| NDP | numeric data product |
| NEP | net ecosystem production |
| NIGEC | National Institute for Global Environmental Change |
| NOAA | National Oceanic and Atmospheric Administration |
| NODC | National Oceanographic Data Center |
| NPP | net primary production |
| NSF | National Science Foundation |
| OACES | Ocean-Atmosphere Carbon Exchange Study |
| ODBC | Open Database Connectivity |
| ODS | Output Delivery System |
| OME | ORNL Metadata Editor |
| ORNL | Oak Ridge National Laboratory |
| OSU | Ohio State University |
| $pCO_2$ | partial pressure carbon dioxide |
| PDA | permanent data archive |
| PDF | portable document format |
| Pg | petagram |
| pH | pH value |
| PICES | North Pacific Marine Science Organization |
| PIs | principal investigators |
| PM | particulate matter |
| PMEL | Pacific Marine Environmental Laboratory |
| ppmv | parts per million by volume |
| pptv | parts per trillion by volume |
| QPHB | *Quality Planning Handbook* |
| QSMP | *Quality Systems Management Plan* |
| QSSC | Quality Systems Science Center |
| R3 | Request Response Record |
| RAID | redundant array of independent disk |
| RIHMI-WDC | Russian Research Institute for Hydrometeorological Information ! World Data Center |
| R/V | Research Vessel |
| SAT | surface-air temperature |
| $SF_5CF_3$ | trifluoromethyl sulphur pentafluoride |
| $SF_6$ | sulphur hexafluoride |
| SIO | Scripps Institution of Oceanography |
| SOS | Southern Oxidants Study |
| SQL | Structured Query Language |
| TALK | total alkalinity |
| $TCO_2$ | total carbon dioxide |
| TDE | Throughfall Displacement Experiment |

| | |
|---|---|
| UN | United Nations |
| UPS | uninterruptible power supply |
| WBW | Walker Branch Watershed |
| WDC | World Data Center |
| WG | Working Group |
| WHP | World Hydrographic Program |
| WOCE | World Ocean Circulation Experiment |
| WWR | World Weather Records |
| XML | eXtensible Markup Language |

# 10. References

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